

EXAM 1

28 September 2000

IMPORTANT: Write clearly and neatly. Make sure that you give some reasoning or working for each answer. Full marks will NOT be awarded for the final answer by itself, UNLESS it is supported by a brief justification or explanation.

Give units for all quantities!

Some data: $R = 8.314 \text{ J K}^{-1} \text{ mol}^{-1}$ $1 \text{ atm} = 101325 \text{ Pa}$ $N_A = 6.022 \times 10^{23} \text{ mol}^{-1}$

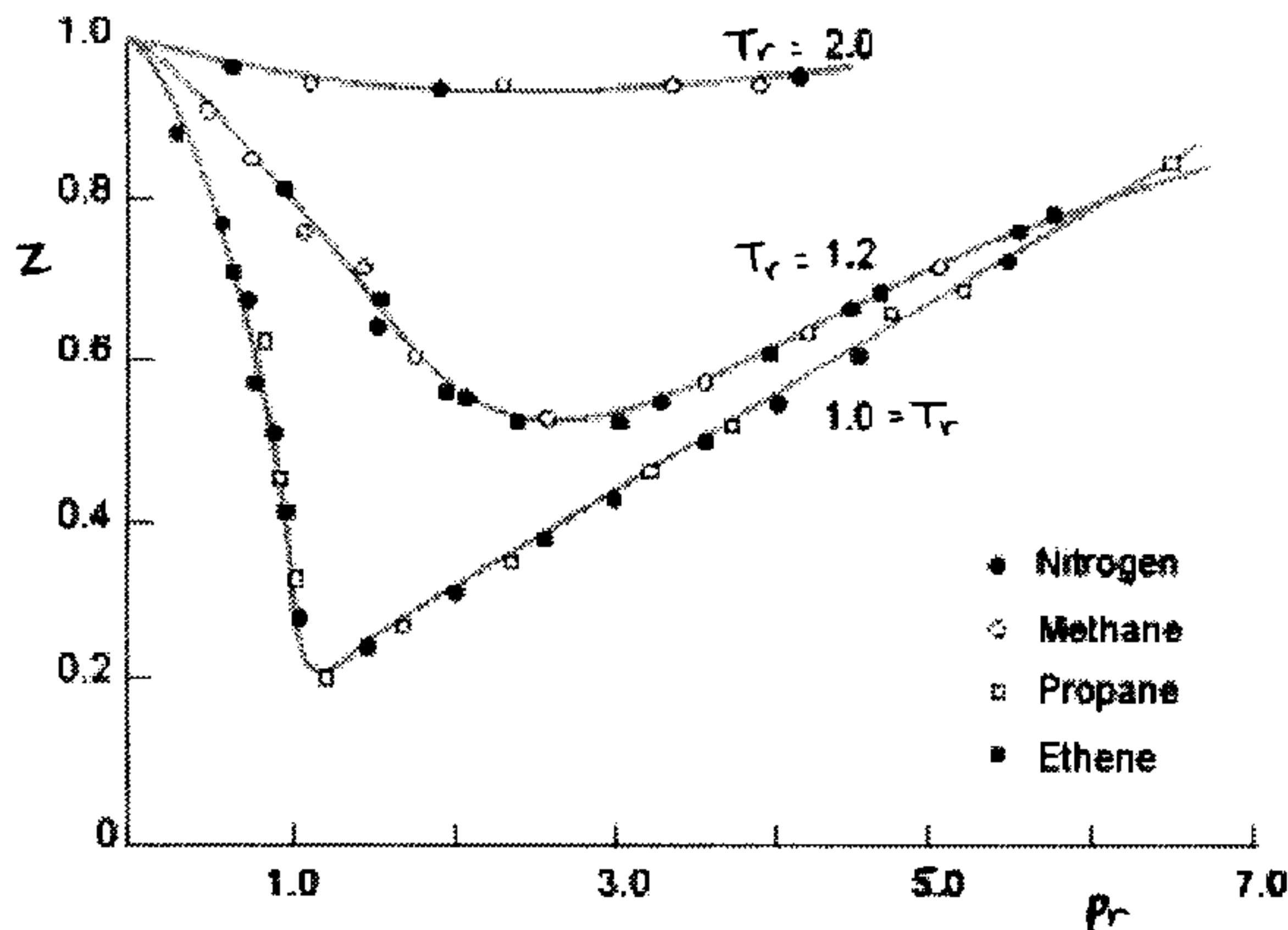
YOUR NAME SOLUTIONS

(1) 20 points

The critical constants for 1 mol of a non-ideal gas are $T_c = 500$ K, $p_c = 4 \times 10^6$ Pa and $V_c = 3.5 \times 10^{-5}$ m³.

a) Use the Law of Corresponding States and the graph below to estimate the compression factor and volume for the gas if it is confined at 1×10^7 Pa and 600 K.

b) In a few lines, discuss in terms of a molecular interpretation why the compression factor in this case is greater than or smaller than the value expected for an ideal gas.



$$a) p_r = p/p_c = 10^7 \text{ Pa} / 4 \times 10^6 \text{ Pa} = 2.5$$

$$T_r = T/T_c = 600/500 = 1.2$$

$$\text{From the graph, } Z \approx 0.5 = \frac{pV}{RT}$$

$$\therefore V = ZRT/p = \frac{0.5 \times 8.314 \times 600}{10^7} \text{ m}^3 = 2.5 \times 10^{-4} \text{ m}^3$$

b) $Z < 1$ so attractive forces dominate.

(2) 40 points

C_v for 1 mol of an ideal gas is 20 J K^{-1} . Calculate q , w , ΔU and ΔH when the temperature is reversibly raised from 300 to 700 K and the initial pressure is 10^5 Pa .

a) At constant volume.

b) At constant pressure.

c) Adiabatically.

$$C_p = C_v + R = 28.314 \text{ J K}^{-1} \text{ here.}$$

$$a) \quad q_v = \int_{300}^{700} C_v dT = 20(700-300) \text{ J} = 8000 \text{ J} = \Delta U \text{ here}$$

because $w=0$.

$$\Delta H = \int_{300}^{700} C_p dT = 28.314(700-300) \text{ J} = 11326 \text{ J.}$$

b) ΔH , ΔU the same.

$$\Delta U = q + w$$

$$q_p = \Delta H$$

$$\therefore w = -3326 \text{ J.}$$

c) ΔU and ΔH the same. $q=0$. $\Delta U = q + w$

$$\therefore w = 8000 \text{ J.}$$

(3) 40 points

Consider the reaction: $\text{H}_2(\text{g}) + \text{F}_2(\text{g}) \rightarrow 2 \text{HF}(\text{g})$ and the following information:

$$C_p(\text{H}_2(\text{g})) = 0.1 T \text{ J K}^{-1} \text{ mol}^{-1} \quad C_p(\text{F}_2(\text{g})) = 10 + 0.1 T \text{ J K}^{-1} \text{ mol}^{-1} \quad C_p(\text{HF}(\text{g})) = 0.2 T \text{ J K}^{-1} \text{ mol}^{-1}$$

where T is the absolute temperature in kelvin. $\Delta_f H_{298}(\text{HF}(\text{g})) = -271 \text{ kJ mol}^{-1}$.

a) Calculate ΔH at 298 K.

b) Calculate ΔH at 2000 K.

c) Make an estimate of what temperature T^* could be reached if 1 mol of H_2 reacted with 1 mol of F_2 , initially both at 298 K, in a fixed volume adiabatic system. Assume the reaction goes to completion. Show work and explain your reasoning.

$$a) \Delta H_{298} = 2 \times -271 - 0 - 0 = -542 \text{ kJ mol}^{-1}.$$

$$b) \Delta C_p = 2 \times 0.2T - 0.1T - (10 + 0.1T) = -10 + 0.2T \text{ J K}^{-1}.$$

$$\begin{aligned} \Delta H_{2000} &= \Delta H_{298} + \int_{298}^{2000} \Delta C_p \cdot dT \\ &= -542000 + \left[-10T + 0.1T^2 \right]_{298}^{2000} = -168 \text{ kJ mol}^{-1}. \end{aligned}$$

c) Heat release at 298 K, $q_r = 542000 \text{ J}$. Assume all goes into heating 2 moles of HF, $C_p = 2 \times 0.2T = 0.4T$.

$$q = \int_{298}^{T^*} C_p dT = \left[0.2T^2 \right]_{298}^{T^*} = \frac{T^{*2}}{5} - 17761 \therefore T^* = \underline{\underline{1673 \text{ K}}}.$$

A better answer accounts for the pV work done as the products expand.

Assume $p_{\text{ext}} = 10^5 \text{ Pa}$. Initial vol. = $\frac{nRT}{P} = 0.05 \text{ m}^3$.

Final vol. = $\frac{nRT^*}{P} = 1.66 \times 10^{-4} T^*$.

pV work done by gas = $p_{\text{ext}} \cdot \Delta V = (16.6 T^* - 5000) \text{ J}$. Add this to q :

$$q = 0.2 T^{*2} + 16.6 T^* - 22761 = 542000.$$

Solution to this quadratic eqn. is 1639 K, slightly lower.